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Cholera Surveillance during the Haiti Epidemic — The First 2 Years

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ABSTRACT

BACKGROUND

In October 2010, nearly 10 months after a devastating earthquake, Haiti was stricken by epidemic cholera. Within days after detection, the Ministry of Public Health and Population established a National Cholera Surveillance System (NCSS).

METHODS

The NCSS used a modified World Health Organization case definition for cholera that included acute watery diarrhea, with or without vomiting, in persons of all ages residing in an area in which at least one case of *Vibrio cholerae* O1 infection had been confirmed by culture.

RESULTS

Within 29 days after the first report, cases of *V. cholerae* O1 (serotype Ogawa, biotype El Tor) were confirmed in all 10 administrative departments (similar to states or provinces) in Haiti. Through October 20, 2012, the public health ministry reported 604,634 cases of infection, 329,697 hospitalizations, and 7436 deaths from cholera and isolated *V. cholerae* O1 from 1675 of 2703 stool specimens tested (62.0%). The cumulative attack rate was 5.1% at the end of the first year and 6.1% at the end of the second year. The cumulative case fatality rate consistently trended downward, reaching 1.2% at the close of year 2, with departmental cumulative rates ranging from 0.6% to 4.6% (median, 1.4%). Within 3 months after the start of the epidemic, the rolling 14-day case fatality rate was 1.0% and remained at or below this level with few, brief exceptions. Overall, the cholera epidemic in Haiti accounted for 57% of all cholera cases and 53% of all cholera deaths reported to the World Health Organization in 2010 and 58% of all cholera cases and 37% of all cholera deaths in 2011.

CONCLUSIONS

A review of NCSS data shows that during the first 2 years of the cholera epidemic in Haiti, the cumulative attack rate was 6.1%, with cases reported in all 10 departments. Within 3 months after the first case was reported, there was a downward trend in mortality, with a 14-day case fatality rate of 1.0% or less in most areas.

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On October 19, 2010, the Haitian Ministry of Public Health and Population's Directorate of Epidemiology, Laboratory and Research was notified of unusually high numbers of patients from 2 of Haiti's 10 administrative departments (similar to states or provinces), Artibonite and Centre, who had presented with acute watery diarrhea and dehydration, in some cases leading to death.[1] On October 21, 2010, the National Public Health Laboratory identified toxigenic *Vibrio cholerae* O1 (serotype Ogawa, biotype El Tor) in stool specimens from several patients.[2] The health ministry immediately informed the public, the Pan American Health Organization (PAHO), and other international authorities of the presence of laboratory-confirmed cholera in Haiti. There was an immediate need for surveillance data to track the anticipated epidemic and inform the public health response.

Compounding the difficulties of addressing rampant cholera were the challenges created by the massive earthquake on January 12, 2010. Despite multisectoral relief efforts, Haiti's infrastructures for health care, water, and sanitation were severely damaged, complicating an already precarious situation. In 2008, an estimated 63% of the 9.8 million persons in Haiti had access to an improved drinking water source (as defined by the World Health Organization [WHO]), with only 12% receiving piped, treated water; only 17% had access to adequate sanitation.[3] Cholera, a waterborne diarrheal disease that is rapidly fatal in severe cases, had not been seen in Haiti for more than a century, as the Caribbean region was untouched by the cholera pandemic that began in Peru in 1991.[4,5] The Haitian population had no previous exposure or acquired immunity to toxigenic *V. cholerae*.[5] Compounding factors, such as the prevalence of malnutrition, blood group O, and hypochlorhydria, may have further contributed to disease severity.[6-8] The Haitian epidemic strain was identified as a variant strain of the El Tor biotype, containing the toxin type found in the Classic biotype, a variant strain that has been associated with more severe illness.[9,10] Attaining the internationally accepted goal of a cholera case fatality rate of 1.0% or less was made more challenging because of these conditions.[1]

In response to the earthquake, the health ministry established two syndrome-based disease-surveillance systems: the National Sentinel Surveillance System and the Internally Displaced Persons Surveillance System.[11,12] Though these systems reported weekly on cases of acute watery diarrhea, they were not designed to handle the magnitude and type of data needed to track an emergent national epidemic. Thus, there was a need for a cholera-specific surveillance system that could capture and summarize daily reports, be immediately operational in affected areas, and be rapidly scalable. This event-based surveillance system built on the existing infrastructure for health care monitoring and evaluation and benefited from lessons learned from activities after the earthquake. This article describes the implementation of a National Cholera Surveillance System (NCSS) and provides 2-year summary data for the epidemic through October 20, 2012.

METHODS

SURVEILLANCE SYSTEM

The NCSS was composed of both governmental and nongovernmental health facilities. Data were collected and reported to the health ministry by health authorities in the departments and communes. The health ministry was further responsible for the management, analysis, and dissemination of all data. Technical staff from the Centers for Disease Control and Prevention (CDC) and the PAHO contributed to the design and continuous improvement of the system.

CASE DEFINITION

The NCSS modified the WHO case definition for cholera of "acute watery diarrhea, with or without vomiting, in a patient aged 5 years or more" to include persons of any age in a cholera-affected department.[13,14] Cases were stratified according to age (<5 years or ≥5 years), which allowed for the tracking of the number of cases that met the WHO case definition. A cholera-affected department was defined as one in which *V. cholerae* O1 had been isolated from at least one stool culture at the national laboratory.[15]

LABORATORY TESTING

Samples of stool were tested by a commercial rapid diagnostic test for *V. cholerae* O1 and O139 (Crystal VC Dipstick, Span Diagnostics) and were inoculated onto thiosulfate–citrate-bile salts–sucrose agar.[14] *V. cholerae* strains were identified, serotyped, and tested for antimicrobial suscepti-

bility at the national laboratory with the use of standard methods.[16] All 10 departments were requested to provide periodic convenience samples of stool specimens from patients meeting the case definition to confirm the ongoing presence of toxigenic *V. cholerae* and for antimicrobial susceptibility testing to inform and monitor the development of treatment guidelines over the course of the epidemic. Since April 2012, an increasing number of stool specimens have been collected in a more systematic fashion through a laboratory-enhanced, health care facility–based sentinel surveillance system for acute watery diarrhea launched by the national laboratory at four sites in three departments.[17]

HOSPITALIZATIONS AND DEATHS

Data were also collected on hospitalizations and deaths. A hospitalization was defined as a case requiring admission to a health care facility for at least 1 night. Deaths were classified as institutional deaths if they occurred within a health care facility or as community deaths if verbal autopsies revealed symptoms consistent with the case definition in persons who died outside a health care facility. Community deaths were reported to health care facilities through a variety of channels, including physicians, community health workers, and local community leaders. Daily tallies of cases, hospitalizations, and deaths were collected with the use of standardized forms. Data transmission between the various levels of the surveillance system was accomplished through a combination of telephone calls, text messages, and e-mails.

SURVEILLANCE DATA

Cholera surveillance data were entered into databases (Excel 2007, Microsoft) that captured daily data from departments, communes (third-level divisions in Haiti, with the 10 departments divided into 140 communes), and facilities. Routine analyses of data from national and department levels with tables and graphs displaying daily and cumulative statistics, including case fatality rates for each department and the Port-au-Prince metropolitan area, were generated daily. Cumulative case fatality rates were calculated as the ratio of the total number of deaths (institutional and community) to the total number of cases. Hospital case fatality rates were calculated as the ratio of new institutional deaths to new hospitalized cases. Average 14-day case fatality rates were calculated as the ratio of new deaths to the number of new cases during the preceding 14-day period.

NCSS data were used to create weekly reports detailing commune-level data, including tables and maps of weekly incidence and cumulative attack rates, calculated as the ratio of the total number of cases (including community deaths) to the overall population. These maps were produced in ArcGIS 10 (ESRI). Reports and maps were posted on the website of the health ministry (www.mspp.gouv.ht).

RESULTS

SURVEILLANCE SYSTEM

Data that were collected for the 10 days from October 20, 2010, to October 29, 2010, through active contact with health facilities were disseminated through daily press conferences held by the health ministry. On October 28, 2010, standardized reporting forms and accompanying case definitions were distributed to the departments, marking the initiation of the NCSS. On October 30, 2010, the health ministry began disseminating daily standardized reports. By November 10, 2010, daily reports from all 10 departments were being sent to the health ministry's Directorate of Epidemiology, Laboratory, and Research. By November 19, 2010, which was 29 days after the first cases were confirmed by culture, all 10 departments were declared to be affected by cholera. Starting on May 23, 2011, the health ministry disseminated weekly reports presenting commune-level data for all 140 communes in Haiti.

LABORATORY TESTING

Through October 20, 2012, the national laboratory had isolated *V. cholerae* O1 serotype Ogawa from 1675 of 2703 stool specimens tested (62.0%). Of these, 511 stool samples (330 positive for *V. cholerae* O1) were obtained through laboratory-enhanced surveillance.[17] Patient sampling for stool culture was nonrandom, but specimens from all 10 departments were tested. All strains that were tested were resistant to furazolidone, nalidixic acid, sulfisoxazole, streptomycin, and trimethoprim–sulfamethoxazole and were susceptible to ampicillin, amoxicillin–clavulanic acid, and tetracycline. No strains were resistant to ciprofloxacin, but all showed decreased susceptibil-

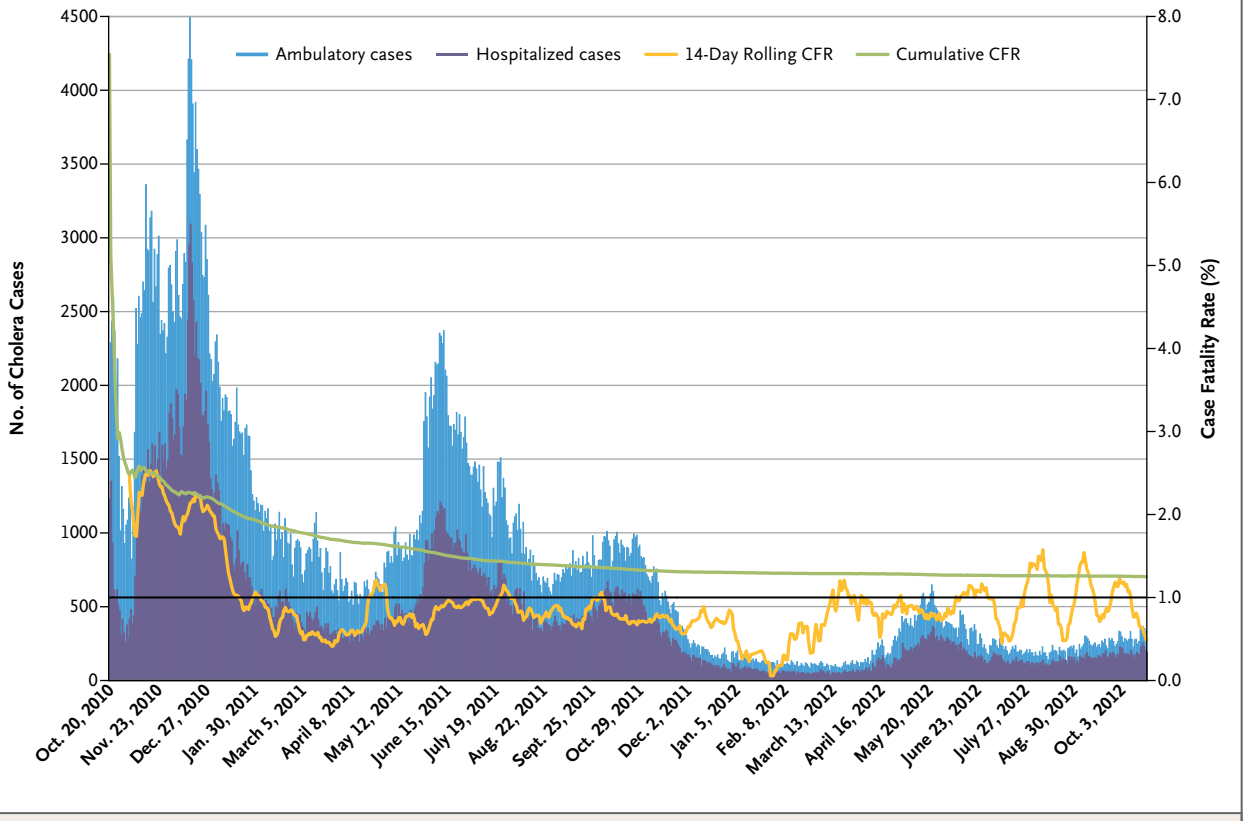

Figure 1. New Cases of Cholera and Hospitalizations in Haiti during a 2-Year Period.

Shown are the number of cases of cholera, as documented from the initiation of surveillance on October 20, 2010, through October 20, 2012, according to whether patients were ambulatory or hospitalized (left axis). Also shown are 14-day and cumulative case fatality rates (CFR) (right axis). The black horizontal line shows the 1.0% case fatality rate.

ity. In addition, a subgroup of isolates that were tested at the national laboratory were also tested at the CDC, where they showed a similar pattern with the typical Haitian profile of resistance to trimethoprim–sulfamethoxazole, furazolidone, nalidixic acid, sulfisoxazole, and streptomycin.[16] Stool samples that were collected from two patients on March 13 and March 14, 2012, yielded *V. cholerae* serotype Inaba, the first evidence of serotype switching.[18] Between March 15, 2012, and October 20, 2012, only two additional *V. cholerae* serotype Inaba isolates were identified.

CASES, HOSPITALIZATIONS, AND DEATHS

Through October 20, 2012, the health ministry reported 604,634 cases of infection, 329,697 hospitalizations, and 7436 deaths from cholera. Children under 5 years of age accounted for 78,938 cases of infection (13.1%), 34,394 hospitalizations (10.4%), and 580 deaths (7.8%), including 460 of 4807 institutional deaths (9.6%) and 120 of 2629 community deaths (4.6%).

Figure 1 shows five distinct peaks in epidemic activity: a short burst in late October 2010 that was largely confined to the departments of Artibonite and Centre; a taller, broader peak from mid-November 2010 through mid-February 2011 as the epidemic spread throughout the country and daily case counts surpassed 4000; a smaller peak from June 2011 through July 2011; a small peak around the time of the 1-year anniversary from mid-September 2011 through mid-November 2011; and the smallest peak from April 2012 through June 2012. Of note, the 7-day average proportion of patients who were under the age of 5 years varied inversely with the total number of reported cases, ranging from a low of 8.2% near the height of the first epidemic peak (consistent with a predominance of disease in adults after the introduction of cholera to Haiti)

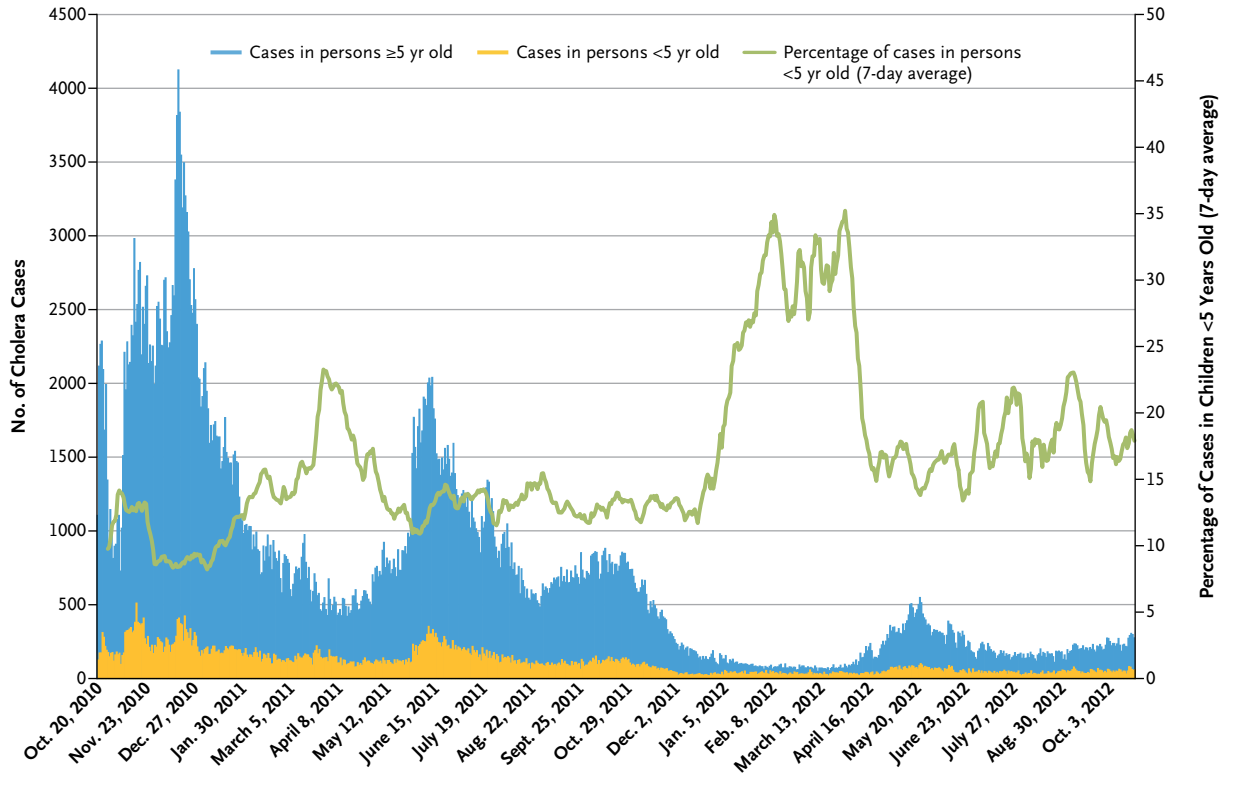

Figure 2. Cases of Cholera in Haiti during a 2-Year Period, According to Age.

Shown are the number of cases of cholera, as documented from the initiation of surveillance on October 20, 2010, through October 20, 2012, according to age (<5 years or ≥5 years) (left axis) and 7-day averages of the percentage of cases in children under the age of 5 years (right axis).

to a high of 35.0% during the 7-day period from March 23, 2012, to March 30, 2012, during the most recent lull in cholera activity (Fig. 2).

The cumulative attack rate was 5.1% at the end of the first year (October 20, 2011) and 6.1% at the end of the second year (October 20, 2012). Maps of the cumulative attack rates drawn according to department (Fig. 3A) and commune (Fig. 3B) show a heterogeneous distribution, with a concentration of communes with a high attack rate bordering the Artibonite River in Artibonite and Centre departments. (Additional figures are provided in the Supplementary Appendix, available with the full text of this article at NEJM.org.) Weekly incidence maps drawn according to commune depicted a moving target of infection, with focal peaks of cholera activity in different communes at different times.

Since November 2010, the national cumulative case fatality rate has for the most part trended downward, with a rate of 1.2% on October 20, 2012. The departmental cumulative case fatality rates at the 2-year mark ranged from 0.6% to 4.6% (median, 1.4%), with the highest being in Grand Anse (4.0%) and Sud-Est (4.6%) (Table 1). Within 3 months after the start of the epidemic, the 14-day case fatality rate reached 1.0% on January 16, 2011, and with the exception of a few short-lived events, has remained at or below this level (Fig. 1).

DISCUSSION

The annual global burden of cholera in 2011 was estimated at 2.8 million cases and 91,000 deaths.[19] The inadvertent introduction of toxigenic *V. cholerae* into Haiti in October 2010 resulted in the world's largest national cholera

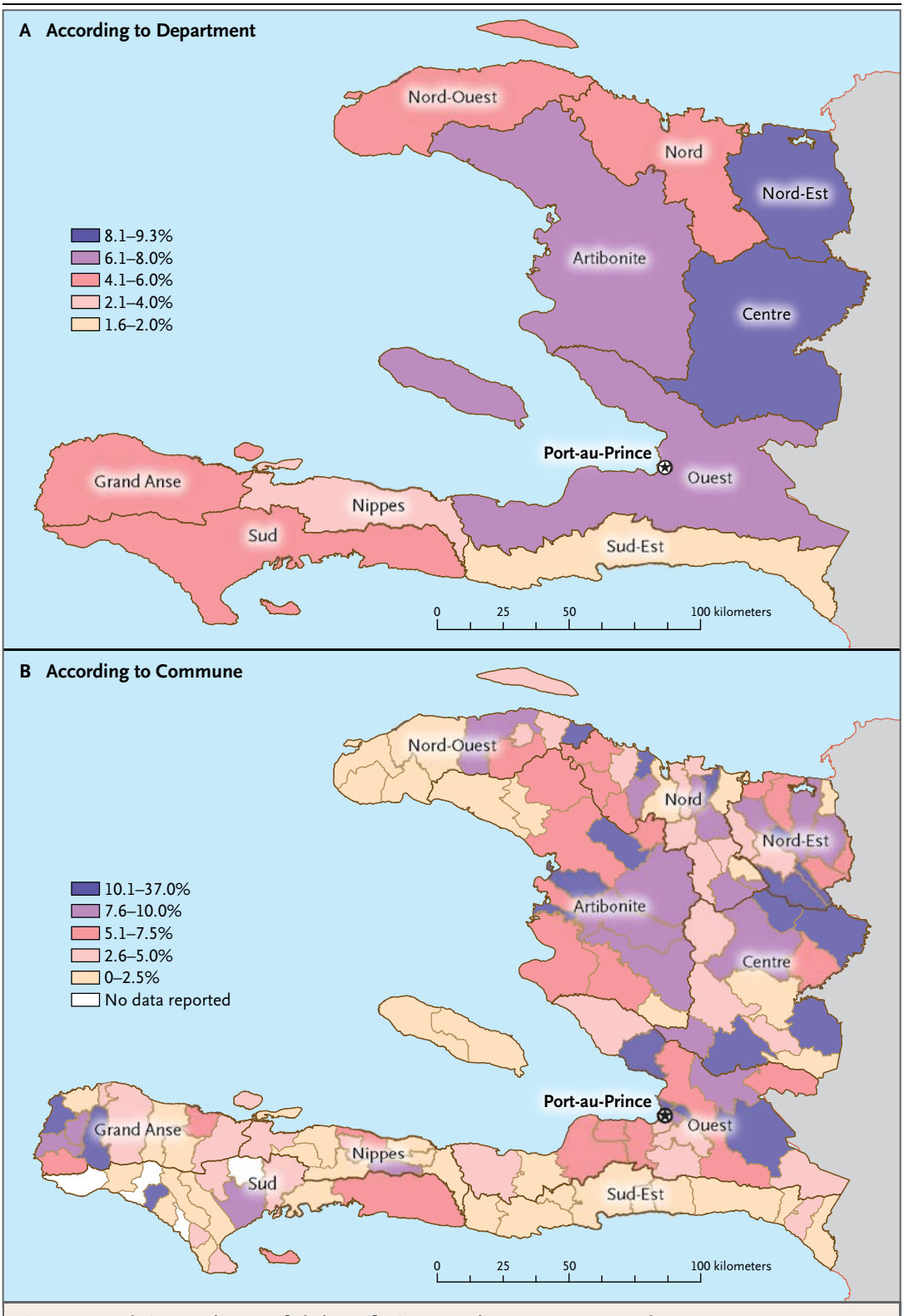

Figure 3. Cumulative Attack Rates of Cholera Infection, According to Department and Commune.

Shown are cumulative attack rates of cholera infection from October 20, 2010, to October 20, 2012, in Haiti, according to department (Panel A) and commune (Panel B).

Table 1. Cumulative Numbers of Reported Cholera Cases, Hospitalizations, and Deaths in Haiti during the 2-Year Epidemic, According to Department.*

Department or City	Cases			Hospitalizations				Deaths			Case Fatality Rate	
	In Patients <5 yr	In Patients ≥5 yr	Total	In Patients <5 yr	In Patients ≥5 yr	Total	Percent of Total Cases	Institutional	Community	Total	Hospital	Cumulative
	no.		*no. (% <5 yr)*	*no.*		*no. (% <5 yr)†*		*no. (% <5 yr)*			%	
All patients	78,938	525,696	604,634 (13.1)	34,394	295,303	329,697 (43.6)	54.5	4807 (9.6)	2629 (4.6)	7436 (7.8)	1.5	1.2
Artibonite	17,939	98,130	116,069 (15.5)	6,225	36,939	43,164 (34.7)	37.2	705 (10.8)	421 (0)	1126 (6.7)	1.6	1.0
Centre	8,636	54,086	62,722 (13.8)	4,365	26,430	30,795 (50.5)	49.1	387 (5.4)	299 (4.0)	686 (4.8)	1.3	1.1
Grande Anse	1,892	20,832	22,724 (8.3)	1,135	14,620	15,755 (60.0)	69.3	408 (7.1)	532 (4.3)	940 (5.5)	2.6	4.0
Nippes	534	7,500	8,034 (6.6)	392	5,266	5,658 (73.4)	70.4	101 (5.0)	106 (0)	207 (2.4)	1.8	2.5
Nord	3,572	53,798	57,370 (6.2)	2,837	48,805	51,642 (79.4)	90.0	813 (2.6)	64 (0)	877 (2.4)	1.6	1.5
Nord-Est	4,286	26,584	30,870 (13.9)	2,112	16,657	18,769 (49.3)	60.8	182 (8.2)	174 (7.5)	356 (7.9)	1.0	1.1
Nord-Ouest	3,557	25,910	29,467 (12.1)	2,191	16,037	18,228 (61.6)	61.9	286 (18.2)	124 (5.6)	410 (14.4)	1.6	1.4
Ouest‡	9,903	63,389	73,292 (13.5)	6,260	40,739	46,999 (63.2)	64.1	748 (13.9)	270 (11.5)	1018 (13.3)	1.6	1.4
Port-au-Prince§	25,518	138,905	164,423 (15.5)	6,830	65,466	72,296 (26.8)	44.0	754 (13.8)	311 (7.1)	1065 (11.8)	1.0	0.6
Sud	2,363	28,197	30,560 (7.7)	1,419	17,180	18,599 (60.1)	60.9	252 (7.9)	65 (9.2)	317 (8.2)	1.4	1.0
Sud-Est	738	8,365	9,103 (8.1)	628	7,164	7,792 (85.1)	85.6	171 (7.6)	263 (2.3)	434 (4.4)	2.2	4.6

* Data are for the period from October 20, 2010, to October 20, 2012. Numbers were updated on November 14, 2012, and do not necessarily match up with provisional data displayed in the official report for October 20, 2012, on the website of the Ministry of Public Health and Population.
† The percentages in this column were calculated as the proportion of all patients under the age of 5 years who were hospitalized.
‡ Values for Ouest do not include those for the city of Port-au-Prince.
§ Values for Port-au-Prince include the communes of Carrefour, Cité Soleil, Delmas, Kenscoff, Pétionville, Port-au-Prince, and Tabarre.

epidemic in recent memory.[20] This epidemic accounted for 57% of all cholera cases and 45% of all deaths from cholera reported to the WHO in 2010 and 2011.[5,10,21-24] As the health ministry, nongovernmental organizations, and public health community at large work to reach consensus on the right mix of public health interventions to prevent cholera from becoming endemic in Hispaniola[25-27] and spreading throughout the region,[28-32] there remains a need for ongoing, systematic cholera surveillance in Haiti.

Haiti's NCSS has a number of the attributes of an effective surveillance system.[33] Its useful outputs have helped direct clinical practice and interventions, informed need-based funding, provided the Haitian government with the ability to track the epidemic and update the global community in a timely fashion, and facilitated the mobilization of support from technical and donor organizations. In the first year, the data provided valuable feedback for forecasting and for the prepositioning of prevention and treatment resources,[34] informing epidemiologic studies,[35-40] and projecting the evolution of the epidemic with the use of specialized epidemiologic models.[34,41-43] More recently, the data have informed technical experts on options for the targeted use of oral cholera vaccine in Haiti.[32] Moreover, the data have been essential for advocating for an international effort to eliminate cholera transmission on the island of Hispaniola led by the governments of Haiti and the Dominican Republic, the PAHO, the United Nations Children's Fund (UNICEF), the CDC, and other partners.[25]

The use of the existing national monitoring and evaluation framework to implement a cholera surveillance system ensured rapid acceptability of the NCSS and maximized the timeliness of reporting. Two days after the detection of the epidemic, the health ministry was able to provide timely reports regarding the number of cases and resulting deaths. A week later, standardized reports were disseminated to a wide audience through the Internet. The number and types of variables collected were kept to the minimum amount necessary to follow the daily numbers of new cases of infection, hospitalizations, and deaths in each affected region, in line with well-defined international guidelines for cholera surveillance.[13,14,44-46] With regard to simplicity, the system proved stable in the face of the civil unrest that followed the first round of presidential elections on November 28, 2010, and disturbances caused by Hurricane Tomas on November 6, 2010.[1] In addition, the system was sensitive enough to detect periodic upsurges in cases often associated with the rainy season.[47]

The standardized reports of the health ministry presented both daily and cumulative case fatality rates. The variance of daily case fatality rates can make trends difficult to discern. In addition, the high mortality in the early days of the epidemic heavily influenced the cumulative case fatality rates, giving the impression of sustained high mortality throughout the reporting period. In contrast, the calculation of a 14-day rolling case fatality rate provided a balance between the daily case fatality rates and the cumulative rates (Fig. 1). The different case fatality rates portray a synopsis of the current situation and trends over time. The cumulative case fatality rate after the initial spike has continued to trend downward and remained low even when the daily numbers of cases and hospitalizations increased. Moreover, within 3 months after the onset of the epidemic, the 14-day case fatality rate reached the internationally accepted goal of 1.0%. Geographic foci of excess cholera morbidity and mortality were routinely identified through data at department and commune levels and through a complementary alert-and-response system that led to targeted follow-up investigations.

The current WHO case definition for cholera excludes children under the age of 5 years because of the high prevalence of acute watery diarrhea in this age group caused by other infections. Nonetheless, children and infants are susceptible to cholera. Although the onset of the epidemic occurred predominantly in adult males working in rice fields, cholera quickly spread among persons of all age groups and both sexes.[48] During epidemic peaks, case counts increased among both children under the age of 5 years and those 5 years of age or older. During epidemic troughs, increases in the proportion of reported cases in children under the age of 5 years were due to a relatively greater decrease in reported cases among older children and adults, rather than an increase in the absolute numbers of cases among younger children and infants (Fig. 2). Of interest, a serosurvey con-

ducted in Grande Saline, Haiti, within the first 6 months of the epidemic showed that children between the ages of 2 and 5 years had the highest prevalence of elevated antibody titers against cholera toxin.[39,40] Therefore, even in countries newly affected by cholera, such as Haiti, outbreaks of acute watery diarrhea that affect children under the age of 5 years may be due to cholera and warrant a vigorous investigation and public health response.

In May 2011, the health ministry made commune-level data publicly available in surveillance reports through its official website (Fig. 3B). Earlier public dissemination of commune-level data by the health ministry and a systematic review of the trends in attack rates according to commune could have further improved the public health response and preparedness efforts by providing information to all partners in order to direct care and treatment. The availability of commune-level data helped focus and direct support for specific cholera treatment centers, particularly in 2012, when decreases in cases and resources led some nongovernmental partners to reduce the number of treatment centers they operated.[1] The dissemination of commune-level data also allowed for targeted, intensified water and sanitation interventions and for the prioritization of sites for potential new interventions, such as the use of an oral cholera vaccine.[32] In addition, the health ministry had access to facility-level data.

The NCSS demonstrated several limitations. Although suspected cholera cases were retrospectively documented by the health ministry as early as October 14, 2010, official surveillance data covered the period beginning October 20, 2010, the date on which stool specimens showing toxigenic *V. cholerae* O1 were first collected. As such, the system was not set up to trace back to the origin of the epidemic.

Second, because the cholera surveillance system is largely facility-based, the true burden of cholera morbidity and mortality is likely to have been underestimated, particularly in remote areas with poor access to health facilities.[37]

Third, although the number of community deaths provided a useful indicator for deaths that occurred outside health facilities at different times and places, the enumeration was not performed by trained medical personnel. Anecdotal evidence from Haiti and elsewhere suggests that community deaths may be underreported.[36,49]

Fourth, although it was difficult to accurately measure the day-to-day completeness of reporting on a national scale, reports were regularly submitted by facilities in the majority of communes. However, completeness was sometimes sacrificed for timeliness, and when necessary, antecedent data were updated during the preparation of daily reports, making historical data dynamic in nature and difficult to analyze. Although reports were disseminated in a timely fashion early in the epidemic, as peak periods waned, timeliness dropped off, requiring periodic interventions to reinvigorate reporting.

Fifth, as with all surveillance systems established for epidemic cholera, the majority of cases in the NCSS were not laboratory-confirmed, and inevitably some cases of acute watery diarrhea caused by pathogens other than *V. cholerae* were misclassified as cholera. Surveillance data on the two age groups suggest that this misclassification was more apparent during epidemic lulls, when background rates of noncholera diarrheal disease among children under the age of 5 years probably represented a higher proportion of reported cases. Using the stricter WHO case definition of acute watery diarrhea in persons 5 years of age or older, the health ministry reported 525,696 cases of infection, 295,303 hospitalizations, and 6856 deaths from cholera through October 20, 2012.

Finally, the laboratory testing of a convenience sample of cholera cases does not permit the quantification of the proportion of cases caused by *V. cholerae* serotype Inaba. Because serotype Ogawa infections provide relatively little immunity against subsequent serotype Inaba infections, the detection of the first serotype Inaba isolates in mid-March 2012 stimulated additional preparedness activities.[18] However, there is no evidence to date to suggest that switching from serotype Ogawa to Inaba has had a major effect on the overall characteristics of the epidemic.

In this crisis, the health ministry established an important precedent for a national surveillance system involving the collaboration of governmental and nongovernmental institutions operating at the commune, department, and

central levels. Dependable and timely surveillance data are the cornerstone to implementing effective public health interventions and monitoring their effect, whether for clinical case management or prevention. The investments in the NCSS have improved the overall surveillance and epidemiologic capacity in Haiti and will further serve to monitor post-earthquake efforts to reduce morbidity and mortality associated with preventable disease.[50]

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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